

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 8/22/96	3. REPORT TYPE AND DATES COVERED Final Technical 4/14/93 - 4/14/96	
4. TITLE AND SUBTITLE Mechanisms & Diagnostics of Ultrashort Pulse Laser Ocular Effects			5. FUNDING NUMBERS F49620-93-1-0301	
6. AUTHOR(S) Prof. James G. Fujimoto			2312/AS	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Research Laboratory of Electronics Massachusetts Institute of Technology 77 Massachusetts Avenue Cambridge, MA 02139			8. PERFORMING ORGANIZATION AFOSR-TR-96 0458	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Office of Scientific Research Building 410 Bolling Air Force Base, DC 20332-0001 NL			SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The objective of our program has been to investigate the mechanisms of short and ultrashort pulse laser retinal injury and to develop and apply new diagnostics for the assessment of retinal injury. A key focus of our effort during this program has been to develop and apply optical coherence tomography (OCT) to investigate the morphology of retinal laser injury. OCT is a new noninvasive optical diagnostic technique for micron scale cross sectional imaging, which can permit the noninvasive imaging of retinal microstructure in situ. Working in collaboration with investigators at Brooks AFB, we have applied OCT to study lesion structure, development, and healing response from laser retinal injury. An increased understanding of the mechanisms of laser retinal injury is relevant to the development of laser safety standards as well as the development and improvement of clinical laser therapies for ocular disease. DTIC QUALITY INSPECTED 4				
14. SUBJECT TERMS			15. NUMBER OF PAGES	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED			16. PRICE CODE	
18. OF THIS PAGE UNCLASSIFIED			19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	
			20. LIMITATION OF ABSTRACT UL	

19961016 125

Final Technical Report for the Air Force Office of Scientific Research
Grant No. F49620-93-1-0301

Mechanisms & Diagnostics of Ultrashort Pulse Laser Ocular Effects
April 14, 1993 - April 14, 1996

Principal Investigator:

Dr. James G. Fujimoto
Department of Electrical Engineering and Computer Science
and Research Laboratory of Electronics
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, MA 02139

2. Objectives

The objective of our program has been to investigate the mechanisms of short and ultrashort pulse laser retinal injury and to develop and apply new diagnostics for the assessment of retinal injury. A key focus of our effort during this program has been to develop and apply optical coherence tomography (OCT) to investigate the morphology of retinal laser injury. OCT is a new noninvasive optical diagnostic technique for micron scale cross sectional imaging, which can permit the noninvasive imaging of retinal microstructure in situ. Working in collaboration with investigators at Brooks AFB, we have applied OCT to study lesion structure, development, and healing response from laser retinal injury. An increased understanding of the mechanisms of laser retinal injury is relevant to the development of laser safety standards as well as the development and improvement of clinical laser therapies for ocular disease.

3. and 4. Status of Effort and Accomplishments / New Findings

Noninvasive Imaging of Retinal Structure using Optical Coherence Tomography

Optical Coherence Tomography is a new medical imaging technique which was developed by our laboratory working in collaboration with MIT Lincoln Laboratory and the New England Eye Center. OCT can perform noninvasive micron scale cross sectional imaging in biological systems. OCT operates in a manner somewhat similar to ultrasound B mode scanning, except that imaging is performed using light rather than sound waves. One of the central components of this program has been the development of OCT technology for the noninvasive imaging of retinal structure and retinal laser lesions. The system that

we developed used 800 nm probe light and achieved an axial resolution of 15 microns.

This technology is enabling for a wide range of investigations ranging from studies of laser retinal injury to the diagnosis and clinical management of retinal diseases.

In-Vivo Imaging of the Evolution of Retinal Laser Lesions using Optical Coherence Tomography

We have performed the first studies which use OCT to image *in vivo* retinal lesions produced by different laser retinal exposure parameters. This investigation was performed in collaboration a multidisciplinary team consisting of investigators from the Armstrong Laboratory at Brooks Air Force Base (specializing in laser retinal injury, safety standards, and veterinary medicine), the Laser Medical Center of Lubeck Germany (specializing in mechanisms of laser injury), and Duke University (clinical ophthalmology). In preliminary studies performed at MIT, we developed an OCT system for retinal tomography and image recording and analysis. This system was transported on site to the Armstrong Laboratory at Brooks Air Force Base where laser exposures were performed.

Laser retinal lesions from several complementary laser sources were investigated. In order to study thermally mediated laser lesions, similar to those used clinically, Argon laser exposures in the 100 ms range were investigated. Short and ultrashort pulse effects were examined using exposures in the nanosecond, picosecond, and femtosecond regime with pulse durations as short as 90 fs. A key advantage of optical coherence tomography is that it permits the *in situ* imaging of retinal lesion morphology in real time. Thus, although OCT does not have as high resolution as histopathology, it can permit repeated imaging of lesions both during their formation and healing.

Studies were performed to image lesions immediately following exposure to track their acute development. In addition, imaging was performed at repeated time intervals post exposure in order to track healing response. Tomographic images of lesions at different time intervals were displayed sequentially to make a movie of lesion development and healing. Retinal images from OCT were also correlated with more conventional endpoints of retinal injury including ophthalmoscopic examination and fluorescein angiography. Detailed histological studies were performed on selected lesions and OCT images were correlated with histopathology. This served the dual purpose of giving accurate histopathological information on the lesion morphology as well as defining a baseline for interpreting structures which were observed in OCT images. This study represents was first investigation of retinal injury using OCT and provided the first *in vivo* view of the microstructure, development, and healing of retinal laser lesions.

Noninvasive Imaging for Cataract Evaluation using OCT

In addition to studies of retinal structure and retinal injury, we have also applied optical coherence tomography for the examination of structures in the anterior eye. Working in collaboration with investigators at the Armstrong Laboratory of Brooks Air Force Base,

we have demonstrated the use of OCT for the noninvasive assessment of cataracts. These studies were performed using geriatric rhesus monkeys from the Brooks Air Force Base Delayed Effects Colony (DEC). Eighteen rhesus monkeys from the DEC and one four year old control rhesus were imaged using OCT, and subsequently evaluated by slit-lamp examination. OCT images were produced and compared to the current and previous cataract grading exams. OCT provided additional information on all opacities (central and peripheral) and provided the information in a log reflective scale format to aid in assessing the extent of the cataract. Studies showed good correlation of OCT images with conventional slit lamp examination and clinical grading of cataracts. In addition OCT provided a detailed map of the structure and morphology for corneal opacities. These studies have the potential for leading to a method for objectively and quantitatively assessing cataract progression. Given the prevalence of cataracts, this concept may be of importance for clinical health care management.

5. Personnel Supported and Associated with Effort

Prof. James G. Fujimoto (Professor, Dept. of Electrical Engineering and Computer Science, MIT)

Dr. Brett Bouma (Postdoctoral Associate, Dept. of Electrical Engineering and Computer Science, MIT)

Stephen Boppart (MD/PhD student Dept. of Electrical Engineering and Computer Science, MIT and Harvard-MIT, Division of Health Sciences and Technology)

Michael Hee (MD/PhD student Dept. of Electrical Engineering and Computer Science, MIT and Harvard-MIT, Division of Health Sciences and Technology)

Collaborators

Dr. William P. Roach (formerly at Armstrong Lab, Brooks AFB, TX)

Dr. Benjamin Rockwell (Armstrong Lab, Brooks AFB, TX)

Dr. Clarence P. Cain, Gary D. Noojin (TASC, San Antonio, TX)

Dr. Cheryl D. DiCarlo (formerly at Occupational and Environmental Health Directorate, Brooks AFB, TX)

Dr. Cynthia A. Toth (Professor, Duke Eye Center, Durham, NC)

Dr. Donald A. Gagliano (U.S. Army Medical Research Directorate, Brooks AFB, San Antonio, TX)

Dr. Reginald Birngruber (Director, Medizinisches Laserzentrum, Lubeck, Germany)

Eric A. Swanson (Assistant Group Leader, MIT Lincoln Laboratory, Lexington, MA)

6. Publications

1. J. A. Izatt, M. R. Hee, G. M. Owen, E. A. Swanson, and J. G. Fujimoto, "Optical coherence microscopy in scattering media," *Opt. Lett.* **19**, 590-592, April 1994.
2. J. A. Izatt, M. R. Hee, E. A. Swanson, C. P. Lin, D. Huang, J. S. Schuman, C. A. Puliafito, and J. G. Fujimoto, "Micrometer-scale resolution imaging of the anterior eye *in vivo* with optical coherence tomography," *Archives of Ophthalmology* **112**, 1584-1589, December 1994.
3. C. A. Puliafito, M. R. Hee, C. P. Lin, E. Reichel, J. S. Schuman, J. S. Duker, J. A. Izatt, E. A. Swanson, and J. G. Fujimoto, "Imaging of macular disease with optical coherence tomography (OCT)," *Ophthalmology* **102**, 217-229, February 1995.
4. M. R. Hee, J. A. Izatt, E. A. Swanson, D. Huang, C. P. Lin, J. S. Schuman, C. A. Puliafito, and J. G. Fujimoto, "Optical coherence tomography of the human retina," *Archives of Ophthalmology* **113**, 325-332, March 1995.
5. M. R. Hee, J. A. Izatt, E. A. Swanson, D. Huang, J. S. Schuman, C. P. Lin, C. A. Puliafito, and J. G. Fujimoto, "Optical coherence tomography for ophthalmic imaging," *IEEE Engineering in Medicine & Biology* **14**, 67-76, January/February 1995.
6. M. R. Hee, C. A. Puliafito, C. Wong, E. Reichel, J. S. Duker, J. S. Schuman, E. A. Swanson, and J. G. Fujimoto, "Optical coherence tomography (OCT) of central serous chorioretinopathy," *Am. J. Ophthalmol.* **120**, 65-74, July 1995.
7. J. G. Fujimoto, M. E. Brezinski, G. J. Tearney, S. A. Boppart, B. Bouma, M. R. Hee, J. F. Southern, and E. A. Swanson, "Optical biopsy and imaging using optical coherence tomography," *Nature Medicine* **1**, 970-972, September 1995.
8. C. A. Toth, R. Birngruber, S. A. Boppart, M. R. Hee, J. G. Fujimoto, C. D. DiCarlo, E. A. Swanson, C. P. Cain, D. Narayan, and W. P. Roach, "Argon Retinal Laser Lesions Evaluate *in vivo* by Optical Coherence Tomography," *American Journal of Ophthalmology*, in press.
9. J. A. Zuclich, S. T. Schuschereba, H. Zwick, S. A. Boppart, J. G. Fujimoto, F. E. Cheney, and B. E. Stuck, "A comparison of laser-induced retinal damage from infrared wavelengths to that from visible wavelengths," submitted for publication to *Lasers and Light in Ophthalmology*, 1996.
10. D. G. Narayan, C. A. Toth, S. A. Boppart, M. R. Hee, J. G. Fujimoto, C. P. Cain, C. D. DiCarlo, W. P. Roach, "A comparison of retinal morphology viewed by optical coherence tomography versus light microscopy," in preparation.

7. Interactions / Transitions:

7a. Participation / Presentations at Conferences

1. J. A. Izatt, M. R. Hee, G. Owen, G. Tearney, E. A. Swanson, and J. G. Fujimoto, "Optical coherence microscopy," Advances in Optical Imaging and Photon Migration Topical Meeting, Orlando, FL, March 21-23, 1994, paper WC1.
2. M. R. Hee, J. A. Izatt, D. Huang, E. A. Swanson, C. P. Lin, J. S. Schuman, C. A. Puliafito, and J. G. Fujimoto, "Micron-resolution optical coherence tomography of the human eye," Advances in Optical Imaging and Photon Migration Topical Meeting, Orlando, FL, March 21-23, 1994, paper WA4.
3. J. A. Izatt, M. R. Hee, D. Huang, E. A. Swanson, C. P. Lin, J. S. Schuman, C. A. Puliafito, and J. G. Fujimoto, "High-speed *in vivo* retinal imaging with optical coherence tomography," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'94, Sarasota, FL, May 1-6, 1994, paper 2208, p. 1729.
4. M. R. Hee, J. A. Izatt, E. A. Swanson, D. Huang, C. P. Lin, J. S. Schuman, C. A. Puliafito, J. Iderfurth, R. Birngruber, and J. G. Fujimoto, "*In vivo* optical coherence tomography of the anterior segment," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'94, Sarasota, FL, May 1-6, 1994, paper 3811, p. 2078.
5. J. A. Izatt, M. R. Hee, G. M. Owen, G. Tearney, E. A. Swanson, and J. G. Fujimoto, "Optical coherence microscopy," Technical Digest of the Conference on Lasers and Electro-Optics, CLEO'94, Anaheim, CA, May 8-13, 1994, paper CTuA4.
6. J. G. Fujimoto, J. A. Izatt, M. R. Hee, B. Bouma, E. A. Swanson, C. P. Lin, and C. A. Puliafito, "Biological imaging using optical coherence tomography," presented at the Fifth International Conference on Laser Applications in Life Sciences (LALS'94), Minsk, Republic of Belarus, June 28-July 2, 1994, plenary presentation.
7. B. Bouma and J. G. Fujimoto, "Nonlinear propagation effects in ultrashort pulse generation," presented at International Workshop on Singularities in Patterns and Collapse: Applications to Semiconductor Lasers and Critical Self-focusing of Ultra-Short Optical Pulses, University College Cork, Cork, Ireland, August 21-26, 1994.
8. J. G. Fujimoto, J. A. Izatt, M. R. Hee, B. Bouma, E. A. Swanson, C. P. Lin, and C. A. Puliafito, "Biological imaging using optical coherence tomography and microscopy," European Quantum Electronics Conference (EQEC'94), Amsterdam, August 28 - September 2, 1994.

9. R. Birngruber, S. A. Boppart, J. G. Fujimoto, C. A. Toth, W. P. Roach, "Noninvasive morphological investigations of laser effects on the retina using optical coherence tomography," Oral presentation, Laserseulnar, Regensburg, Germany, December, 1994.
10. M. R. Hee, J. A. Izatt, S. A. Boppart, J. G. Fujimoto, E. A. Swanson, C. P. Lin, J. S. Schuman, C. Wong, and C. A. Puliafito, "Examination of the retina with optical coherence tomography," Biomedical Optics Symposium, Photonics West'95, San Jose, CA, February 4-10, 1995, paper 2393-24.
11. G. J. Tearney, M. R. Hee, J. A. Izatt, B. Bouma, J. G. Fujimoto, M. B. Brezinski, J. F. Southern, R. R. Anderson, and E. A. Swanson, "Optical coherence tomography in multiply scattering tissue," Biomedical Optics Symposium, Photonics West'95, San Jose, CA, February 4-10, 1995, paper 2389-05.
12. R. Birngruber, M. R. Hee, S. A. Boppart, J. G. Fujimoto, E. A. Swanson, C. A. Toth, C. D. DiCarlo, C. P. Cain, G. D. Noojin, and W. P. Roach, "*In vivo* imaging of the development of linear and non-linear retinal laser effects using optical coherence tomography in correlation with histopathological findings," Biomedical Optics Symposium, Photonics West'95, San Jose, CA, February 4-10, 1995, paper 2391-03.
13. C. D. DiCarlo, S. A. Boppart, M. R. Hee, J. G. Fujimoto, D. A. Gagliano, E. A. Swanson, A. B. Cox, R. Amnotte, A. B. Smith, and W. P. Roach, "A new noninvasive imaging technique for cataract evaluation in the rhesus monkey," Biomedical Optics Symposium, Photonics West'95, San Jose, CA, February 4-10, 1995, paper 2395-105.
14. S. A. Boppart, M. R. Hee, J. G. Fujimoto, R. Birngruber, C. A. Toth, E. A. Swanson, C. P. Cain, G. D. Noojin, C. D. DiCarlo, and W. P. Roach, "Dynamic evolution and *in vivo* tomographic imaging of laser-induced retinal lesions using optical coherence tomography," MIT-Harvard Health Science and Technology Forum, March 16, 1995.
15. D. A. Gagliano, C. D. DiCarlo, S. A. Boppart, A. B. Cox, D. X. Hammer, J. G. Fujimoto, M. R. Hee, E. A. Swanson, W. P. Roach, and B. E. Stuck, "Optical coherence tomography (OCT) evaluation of lenticular opacification in non-human primates," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'95, Fort Lauderdale, FL, May 14-19, 1995, paper 3699, p. 799.
16. J. P. Gallo, M. R. Hee, C. A. Puliafito, C. Wong, E. Reichel, J. S. Duker, J. S. Schuman, E. A. Swanson, and J. G. Fujimoto, "Optical coherence tomography (OCT) of central serous chorioretinopathy," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'95, Fort Lauderdale, FL, May 14-19, 1995, paper 954, p. 208.

17. M. R. Hee, C. A. Puliafito, C. Wong, J. S. Duker, E. Reichel, J. S. Schuman, E. A. Swanson, and J. G. Fujimoto, "Cross-sectional imaging of macular holes and vitreo-macular traction with optical coherence tomography (OCT)," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'95, Fort Lauderdale, FL, May 14-19, 1995, paper 952, p. 207.
18. T. Pedut-Kloizman, J. S. Schuman, M. R. Hee, C. Wong, W. Scott, E. Hertzmark, C. A. Puliafito, J. A. Izatt, J. G. Fujimoto, and E. A. Swanson, "Quantitative assessment of nerve fiber layer thickness in cynomolgus monkey eyes *in vivo* using optical coherence tomography," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'95, Fort Lauderdale, FL, May 14-19, 1995, paper 4482, p. 972.
19. C. A. Puliafito, M. R. Hee, C. Wong, J. S. Duker, E. Reichel, B. Rutledge, J. S. Schuman, E. A. Swanson, and J. G. Fujimoto, "Quantitative assessment of macular edema with optical coherence tomography (OCT)," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'95, Fort Lauderdale, FL, May 14-19, 1995, paper 950, p. 207.
20. J. S. Schuman, M. R. Hee, T. Pedut-Kloizman, C. Wong, A. V. Arya, E. Hertzmark, C. A. Puliafito, J. G. Fujimoto, E. A. Swanson, and J. A. Izatt, "Reproducibility of nerve fiber layer thickness measurements using optical coherence tomography," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'95, Fort Lauderdale, FL, May 14-19, 1995, paper 4480, p. 971.
21. J. S. Schuman, M. R. Hee, C. A. Puliafito, C. Wong, T. Pedut-Kloizman, C. P. Lin, E. Hertzmark, J. A. Izatt, E. A. Swanson, and J. G. Fujimoto, "Quantification of nerve fiber layer thickness in normal and glaucomatous eyes using optical coherence tomography: a pilot study," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'95, Fort Lauderdale, FL, May 14-19, 1995, paper 1823, p. 389.
22. C. A. Toth, R. Birngruber, J. G. Fujimoto, W. P. Roach, S. A. Boppart, M. R. Hee, C. D. DiCarlo, and C. P. Cain, "Correlation between optical coherence tomography, clinical examination, and histopathology of macular laser lesions," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'95, Fort Lauderdale, FL, May 14-19, 1995, paper 949, p. 207.
23. C. Wong, M. R. Hee, C. A. Puliafito, J. S. Duker, E. Reichel, B. Rutledge, J. S. Schuman, E. A. Swanson, and J. G. Fujimoto, "Imaging of macular degeneration and choroidal neovascularization with optical coherence tomography (OCT)," Technical Digest of the Annual Meeting of the Association for Research in Vision and

Ophthalmology, ARVO'95, Fort Lauderdale, FL, May 14-19, 1995, paper 1093, p. 240.

24. G. J. Tearney, M. B. Brezinski, M. R. Hee, B. Bouma, J. A. Izatt, J. F. Southern, E. A. Swanson, and J. G. Fujimoto, "Optical biopsy in human tissue using optical coherence tomography and microscopy," Technical Digest of the Conference on Lasers and Electro-Optics, CLEO'95, Baltimore, MD, May 21-26, 1995, paper CThN3.
25. S. A. Boppart, M. R. Hee, J. G. Fujimoto, R. Birngruber, C. A. Toth, E. A. Swanson, C. P. Cain, G. D. Noojin, C. D. DiCarlo, and W. P. Roach, "Dynamic evolution and *in vivo* tomographic imaging of laser-induced retinal lesions using optical coherence tomography," Technical Digest of the Conference on Lasers and Electro-Optics, CLEO'95, Baltimore, MD, May 21-26, 1995, paper CFK4.
26. W. P. Roach, C. D. DiCarlo, S. A. Boppart, D. A. Gagliano, D. X. Hammer, A. B. Cox, M. A. Hanes, M. R. Hee, E. A. Swanson, B. A. Rockwell, and J. G. Fujimoto, "New imaging technique for *in vivo* tomographic cataract evaluation using optical coherence tomography," post-deadline oral presentation and paper, Conference on Lasers and Electro-Optics, CLEO'95, Baltimore, MD, May 21-26, 1995.
27. J. G. Fujimoto, "Biomedical imaging with optical coherence tomography," invited paper presented at the Laser Medicine Congress (LASER'95), Munich, Germany, June 19-23, 1995.
28. J. G. Fujimoto, "Biomedical imaging and optical biopsy using optical coherence tomography," invited paper presented at the 15th International Conference on Coherent and Nonlinear Optics (ICONO'95), St. Petersburg, Russia, June 27 - July 1, 1995.
29. R. Birngruber, S. A. Boppart, C. A. Toth, M. R. Hee, J. G. Fujimoto, E. A. Swanson, C. D. DiCarlo, C. P. Cain, G. D. Noojin, and W. P. Roach, "Optical coherence tomography of chorio-retinal structures: a new noninvasive diagnostic tool with microscopic resolution," oral presentation, German Ophthalmological Society Annual Meeting, Lubeck, Germany, September, 1995.
30. J. G. Fujimoto, G. Tearney, B. Bouma, S. A. Boppart, M. Hee, E. A. Swanson, C. A. Puliafito, J. Schuman, and M. Brezinski, "Biomedical imaging and optical biopsy using optical coherence tomography," invited paper presented at the IXth International Symposium on Ultrafast Processes in Spectroscopy, UPS'95, Trieste, Italy, October 30-November 3, 1995.
31. S. A. Boppart, M. E. Brezinski, B. Bouma, G. J. Tearney, E. A. Swanson, and J. G. Fujimoto, "In vivo imaging of developing morphology using optical coherence tomography," presented at the 1995 American Society of Cell Biology Meeting, Washington, DC, December 9-13, 1995.

32. S. A. Boppart, G. J. Tearney, B. Bouma, J. G. Fujimoto, and M. E. Brezinski, "Optical coherence tomography of embryonic morphology during cellular differentiation," Technical Digest of the Meeting on Advances in Optical Imaging and Photon Migration (AOPM'96) Meeting, Orlando, FL, March 18-20, 1996, paper AWA4-1, p.223.
33. G. J. Tearney, B. E. Bouma, S. A. Boppart, B. Golubovic, E. A. Swanson, and J. G. Fujimoto, "High speed optical coherence tomography," Technical Digest of the Meeting on Advances in Optical Imaging and Photon Migration (AOPM'96) Meeting, Orlando, FL, March 18-20, 1996, paper AWA2-1, p.217.
34. J. G. Coker, C. A. Puliafito, M. R. Hee, J. S. Duker, E. Reichel, J. R. Wilkins, J. S. Schuman, E. A. Swanson, and J. G. Fujimoto, "Optical coherence tomography of retinal inflammatory diseases," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'96, Fort Lauderdale, FL, April 21-26, 1996, paper 2831, p.S612.
35. C. A. Puliafito, J. S. Duker, E. Reichel, J. G. Coker, J. S. Schuman, E. A. Swanson, and J. G. Fujimoto, "Characterization of epiretinal membranes using optical coherence tomography," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'96, Fort Lauderdale, FL, April 21-26, 1996, paper 4375, p.S956.
36. C. A. Puliafito, M. R. Hee, C. R. Baumal, J. S. Duker, E. Reichel, J. R. Wilkins, J. G. Coker, J. S. Schuman, E. A. Swanson, and J. G. Fujimoto, "Optical coherence tomography of age-related macular degeneration and choroidal neovascularization," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'96, Fort Lauderdale, FL, April 21-26, 1996, paper 4376, p.S956.
37. L. Pieroth, J. S. Schuman, M. R. hee, E. Hertzmark, T. Pedut-Kloizman, J. G. Coker, J. R. Wilkins, C. A. Puliafito, C. Mattox, O. S. Singh, J. G. Fujimoto, and E. A. Swanson, "Evaluation of focal defects in the nerve fiber layer using optical coherence tomography," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'96, Fort Lauderdale, FL, April 21-26, 1996, paper 5030, p.S1094.
38. D. Huang, M. R. Hee, T. Pedut-Kloizman, J. R. Wilkins, J. G. Coker, C. A. Puliafito, J. G. Fujimoto, and J. S. Schuman, "A new algorithm for retinal nerve fiber layer thickness measurement by optical coherence tomography," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'96, Fort Lauderdale, FL, April 21-26, 1996, paper 5040, p.S1096.

39. S. Roh, R. J. Noecker, J. S. Schuman, J. J. Weiter, T. R. Hedges, M. R. Hee, J. R. Wilkins, J. G. Coker, C. A. Puliafito, J. G. Fujimoto, E. A. Swanson, and C. Mattox, "Effect of optic disk drusen on nerve fiber layer thickness measured by optical coherence tomography," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'96, Fort Lauderdale, FL, April 21-26, 1996, paper 5044, p.S1096.
40. J. S. Schuman, T. Pedut-Kloizman, L. Pieroth, E. Hertzmark, M. R. Hee, J. R. Wilkins, J. G. Coker, C. A. Puliafito, J. G. Fujimoto, and E. A. Swanson, "Quantitation of nerve fiber layer thickness loss over time in the glaucomatous monkey model using optical coherence tomography," Technical Digest of the Annual Meeting of the Association for Research in Vision and Ophthalmology, ARVO'96, Fort Lauderdale, FL, April 21-26, 1996, paper 5255, p.S1150.
41. J. A. Zuclich, S. T. Schuschereba, H. Zwick, S. A. Boppart, J. G. Fujimoto, F. Cheney, B. E. Stuck, "A comparison of laser-induced retinal damage from 'eye-safe' IR wavelengths to that from visible wavelengths," Oral presentation, Fifth International Congress on Laser Technology in Ophthalmology, Lugano, Switzerland, June 26-29, 1996.

7b and 7c. Consultative and advisory functions / Transitions

- (a) Collaborative studies at the Armstrong Laboratory of Brooks Air Force, Optical Radiation Division (Drs. W.P. Roach, B. Rockwell) investigated the structure and evolution of short pulse retinal injury using OCT. Other collaborators included the Occupational and Environmental Health Directorate (Dr. Cheryl DiCarlo), TASC (Drs. C. Cain and G. Noojin), Duke Eye Center, University Medical School (Dr. C. Toth) and the Laser Medical Center of Lubeck Germany (Dr. R. Birngruber).
- (b) Collaborative studies with the Occupational and Environmental Health Directorate (Dr. Cheryl DiCarlo) and the U.S. Army Medical Research Detachment of Brooks AFB (Dr. D. Gagliano) investigated the grading and imaging of cataracts using OCT.
- (c) Collaborative studies with 1995 MIT Lincoln Laboratory (E. Swanson) investigated the development of new OCT technology.
- (d) Collaborative studies with , the New England Eye Center of the Tufts University School of Medicine (Dr. Carmen Puliafito) investigated the imaging of the normal retina and macular disease in clinical subjects.

8. New discoveries, inventions, patent disclosures

None.

9. Awards, honors

P.I. James G. Fujimoto was General Co-Chair for the Quantum Electronics and Lasers Science Conference, June 1996, Anaheim, CA; Program Co-Chair for the Ultrafast Phenomena conference, May 1996, San Diego, CA; Program Chair for the Optical Imaging and Photon Migration Conference, March 1996, Orlando, FL. He was also elected Fellow of the Optical Society of America (1995) and the IEEE (1995).